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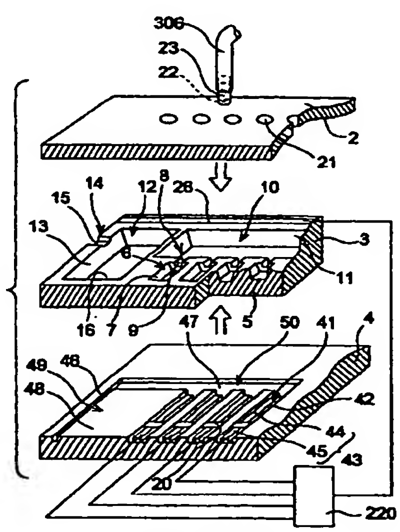
(54) ELECTROSTATIC ACTUATOR, ITS MANUFACTURING METHOD, AND LIQUID INJECTION DEVICE USING THEM

(57) An electrostatic ink jet head (1) using an electrostatic actuator and its manufacturing method, comprising pressure chambers (6) communicating with ink nozzles (21) and an atmospheric pressure chamber (12) open to the atmosphere, wherein diaphragms (5) are formed on the bottom surfaces of the pressure chambers (6), a voltage is applied between the diaphragms (5) and electrodes (43) to vibrate the diaphragms (5) electrostatically so as to inject ink droplets, vibration chambers (41) communicate with a pressure compensating chamber (49), a displacement plate (16) which is displaceable toward the outside of the bottom surface of the pressure compensating chamber (49) according to a variation in atmospheric pressure is formed on the bottom surface of the pressure compensating chamber (49), the volume of the pressure compensating chamber (49) is increased or decreased according to the displacement of the displacement plate (16) so that the inside pressure of each vibration chamber (41) communicating with the pressure compensating chamber (49) is regulated to the atmospheric pressure, whereby the vibration characteristics of the diaphragms (5) can be kept constant even if the atmospheric pressure is varied so as to maintain an appropriate ink-droplet injecting operation.



First Embodiment

FIG.2

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Description

[Technical Feild]

[0001] The present invention relates to an electrostatic actuator which generates pressure by displacing a vibrating plate with electrostatic force, and to a manufacturing method therefor, and also relates to a liquid discharging device for discharging droplets such as an ink-jet head, using the same. More particularly, the present invention relates to an electrostatic liquid discharging device such as an ink-jet head printer for example, capable of continually performing proper droplet discharging action regardless of external atmospheric pressure fluctuations.

[Background Art]

[0002] The background art will flow be described with an ink-jet printer as an example of an electrostatic liquid discharging device. An ink-jet printer having an electrostatic Ink-jet head is disclosed in Japanese Unexamined Patent Application Publication No. 6-55732, for example. With this type of ink-jet head, Ink within a pressure chamber is discharged from an ink nozzle by vibrating a vibrating plate forming a portion of the pressure chamber wherein ink liquid is stored, by electrostatic force. Accordingly, changes in the external atmospheric pressure alter the discharge properties of the ink droplets, which may cause a problem in that the desired ink droplets may not be discharged.

[0003] That is, with an electrostatic ink-jet head, a vibrating plate defining a portion of the pressure chamber faces an electrode plate across a narrow gap, and the vibrating plate is vibrated by electrostatic force by applying driving voltage between the electrode plate and the vibrating plate. The gap between the vibrating plate and the electrode plate is extremely narrow, around 1 to 2 microns, so the space between the vibrating plate and the electrode plate is sealed to form a sealed chamber, so that the vibration of the vibrating plate is not inhibited by intrusion of dust and the like therebetween.

[0004] In the event that the external atmospheric pressure fluctuates, the vibrating plate separating the pressure chamber and the sealed chamber from one another is displaced in a direction such that the pressure within the sealed chamber matches that of the external atmospheric pressure. Consequently, even in a state in which voltage has not been applied, the vibrating plate is in a state of having already been displaced. Thus, in the event that the external atmospheric pressure fluctuates, the vibrating properties of the vibrating plate change even when the same driving voltage is applied, and the discharging properties of the ink droplets (the amount of ink per discharged droplet and the discharging speed of the ink droplets) change.

[0005] Ink-jet printers having a bubble-jet ink-jet head disclosed in Japanese Unexamined Patent Application Publication No. 4-284255 are known. This Unexamined Patent Application Publication discloses a method for performing a continuously stable ink droplet discharging action regardless of fluctuations in the external atmospheric pressure, by detecting the ambient atmospheric pressure and changing the voltage waveform applied to an electro-thermal converting member, that is to say, the driving voltage waveform of the ink-jet head, according to the external atmospheric pressure.

[0006] This method is effective for ink-jet heads according to the bubble-jet method wherein ink liquid within the pressure chamber is heated and caused to bubble, but is seldom advantageous when applied to electrostatic ink-jet heads. Particularly, in environments such as high elevations where the atmospheric pressure differs markedly from normal, merely adjusting the driving voltage waveform for driving the vibrating plate may not be sufficient to facilitate appropriate droplet discharge.

[0007] Electrostatic actuators may be applied to other devices besides the ink-jet printer given hero as an example, such as fuel injection devices for internal combustion engines, atomizers for discharging or spraying liquids such as perfume, and micro-pumps, but with these devices as well, it is thought that the droplet discharge properties fluctuate according to fluctuation of the external atmospheric pressure.

[0008] It is an object of the present invention to provide an electrostatic actuator capable of reliably generating a desired pressure unaffected by fluctuations of the external atmospheric pressure, and an electrostatic liquid discharging device capable of discharging droplets in an appropriate manner.

[Disclosure of the Invention]

[0009] In order to achieve the above objects, the electrostatic actuator according to the present invention comprises a vibrating plate, an electrode plate facing the vibrating plate, and a sealed chamber formed between the electrode plate and the vibrating plate; wherein the vibrating plate is displaced by electrostatic force, by applying voltage between the vibrating plate and the electrode plate; the electrostatic actuator having a pressure compensating means for decreasing the pressure difference between the internal pressure in the sealed chamber and the external pressure.

[0010] The pressure compensating means employed may comprise a pressure compensating chamber communicating with the sealed chamber, and may be capable of increasing/decreasing its volume according to the external atmospheric pressure.

[0011] In this case, the entire pressure compensating chamber might be formed of an expanding/contracting material, or a portion of the pressure compensating chamber may be defined by a displacement plate displaceable in the direction perpendicular to its plane,

according to the external atmospheric pressure.

[0012] The displacement plate is only slightly spaced apart from the facing wall of the pressure compensating chamber; therefore, if the external atmospheric pressure is high, the displacement plate may be displaced far enough to come into contact with the opposing inner wall, thereby inhibiting a further pressure compensating function. Also, in the event that the displacement plate is displaced towards the facing wall, the compliance thereof decreases, which may also result in the inhibition of pressure compensating functions. Accordingly, the displacement plate is preferably curved into a form so as to protrude in a direction away from the facing inner wall of the pressure compensating chamber.

[0013] An arrangement may be used wherein a displacement plate displaceable in the direction perpendicular to its plane is provided as a portion of the pressure compensating chamber instead of the displacement plate which is displaced according to the external atmospheric pressure, and wherein the displacement plate and electrode plate are positioned facing one another, so that the displacement plate can be displaced according to changes in the external atmospheric pressure, by electrostatic force.

[0014] On the other hand, the pressure compensating means may comprise a heat-generating member capable of at least heating gas sealed in the sealed chamber, instead of the pressure compensating chamber. Heating the sealed gee with the heat-generating member raises the internal pressure thereof, so the pressure difference with the external atmospheric pressure can be relieved.

[0015] A preferable material used for configuring the electrostatic actuator is a semiconductor substrate which can be worked with precision. For example, doping a semiconductor substrate with boron, etching the semiconductor substrate, and using the boron doped layer as a displacement plate, allows a displacement plate with desirable properties (compliance) to be obtained. Also, in order to form the electrostatic actuator In a compact size, the vibrating plate and displacement plate are preferably sectioned and formed using a common semiconductor substrate.

[0016] Also, the electrostatic liquid discharging device according to the present invention uses the pressure of the above electrostatic actuator having the pressure compensating functions, as the pressure generating source for discharging droplets. That is, the electrostatic liquid discharging device comprises a nozzle for discharging droplets, and a pressure chamber communicating with the nozzle and also holding liquid, wherein a vibrating plate provided as a wall portion of the pressure chamber is vibrated by the above-described electrostatic actuator, thereby providing the liquid in the pressure chamber with a pressure fluctuation for discharging droplets.

[0017] Common ink-jet heads serving as liquid discharging devices are provided with multiple ink nozzles, with pressure chambers provided corresponding to each ink nozzle, and with a common ink chamber (common liquid chamber) for supplying ink liquid to the pressure chambers provided.

[0018] A diaphragm displaceable in the direction perpendicular to its plane is in some cases formed at the common ink chamber, so that pressure fluctuations in each of the communicating pressure chambers are not transmitted to the side of the neighboring pressure chamber. In the case of applying the present invention to such an ink-jet head, the diaphragm may also serve as the displacement plate. Also, in order to form the device or a portion thereof (the ink-jet head) in a compact size, the pressure chamber, the common ink chamber, and the pressure compensating chamber are preferably sectioned and formed using a common semiconductor substrate.

[0019] In particular, with a liquid discharging device comprising an electrostatic actuator of a configuration wherein the displacement plate of the pressure compensating chamber is displaced by electrostatic force, the configuration may have an external atmospheric pressure detecting means for detecting the external atmospheric pressure, end a control means for driving the displacement plate according to the detected external atmospheric pressure.

[0020] Also, with a liquid discharging device having an electrostatic actuator comprising the heat-generating member, the configuration may have an external atmospheric pressure detecting means for detecting the external atmospheric pressure, and a control means for driving the heat-generating member according to the detected external atmospheric pressure.

[0021] The external atmospheric pressure detecting means may be of a configuration comprising an electrostatic capacity detecting means for detecting the electrostatic capacity between the vibrating plate and the electrode plate, and thereby estimating the external atmospheric pressure band on the detected electrostatic capacity.

[0022] The method for manufacturing the electrostatic actuator according to the present invention is a method for manufacturing an electrostatic actuator comprising a vibrating plate, an electrode plate facing the vibrating plate, and a vibrating chamber formed between the electrode plate and the vibrating plate, wherein the vibrating plate is displaced by electrostatic force, by applying voltage across the vibrating plate and the electrode plate, the method comprising: a process for forming a pressure compensating chamber communicating with the vibrating chamber; a process for forming a displacement plate at a portion of the pressure compensating chamber, displaceable according to the external atmospheric pressure, into a warped form curved so as to protrude in a direction away from the facing inner wall of the pressure compensating chamber; and a process for shutting off and sealing the pressure compensating chamber from the external atmosphere. along with the

vibrating chamber. Furthermore, the air pressure for sealing the pressure compensating chamber may be adjusted. Accordingly, the initial warping of the displacement plate is adjusted, and a displacement plate with desired compliance properties can be obtained.

[Brief Description of the Drawings]

[0023]

Fig. 1	is a schematic configuration diagram illustrating an overview of an ink-jet printer mechanism to which the present invention is applicable.
Fig. 2	is a disassembled perspective view illustrating the ink-jet head of an ink-jet printer relating to a first embodiment of the present invention.
Fig. 3	is a schematic longitudinal cross-sectional diagram of the ink-jet head shown in Fig. 2.
Fig. 4	is a schematic crossways cross-sectional diagram of the ink-jet head shown in Fig. 2.
Fig. 5	is an explanatory diagram illustrating the electrode position of the ink-jet head shown in Fig. 2.
Fig. 6	is a schematic configuration diagram illustrating the control system of the ink-let printer shown in Fig. 1.
Fig. 7	is a schematic partial cross-sectional diagram illustrating the principal portions of the pressure compensating means of the ink-jet head relating to a second embodiment of the present invention.
Fig. 8	is a graph illustrating the compliance properties of the displacement plate of the ink-jet head shown in Fig. 7.
Fig. 9	is an explanatory diagram illustrating the behavior of the displacement plate of the ink-jet head shown in Fig. 7.
Fig. 10	is a schematic partial cross-sectional diagram illustrating the principal portions of the ink-jet head relating to a third embodiment of the present invention.
Fig. 11	is an explanatory diagram illustrating the placement relationship between the vibrating chamber and pressure compensating chamber of the ink-jet head shown In Fig. 10.
Fig. 12	is an explanatory diagram illustrating another example of the placement relationship between the vibrating chamber and pressure compensating chamber.
Fig. 13	is a schematic partial cross-sectional diagram illustrating an improved example of the ink-jet head shown in Fig. 10.
Figs. 14(Aand (B)	are a schematic partial cross-sectional diagram relating to a fourth embodiment of the ink-jet head of the present invention, and an explanatory diagram illustrating the placement relationship between the vibrating chamber and pressure compensating chamber.
Figs. 15(A) and (B)	are explanatory diagrams illustrating the pressure compensation action of the ink-jet head shown in Fig. 14.
Fig. 16	Is a schematic configuration diagram illustrating the deriving control mechanism of the displacement plate of the ink-jet head shown In Fig. 14.
Fig. 17	Is a schematic partial cross-sectional diagram illustrating the principal portions of the ink-jet head relating to a fifth embodiment of the present invention.
Fig. 18	is a schematic configuration diagram of the control mechanism of the heat control member in the ink-jet head shown in Fig. 17.
Fig. 19	is a schematic configuration diagram illustrating another example of the control mechanism of

the heat control member in the ink-jet head shown in Fig. 17.

Fig. 20 is an explanatory diagram illustrating another example of the ink-jet head according to the present invention.

[Best Mode for carrying out the Invention]

[0024] Embodiments of the present invention will be described below with reference to the drawings. The embodiments are described with respect to an ink-jet printer as an example, but the present invention is also applicable to liquid discharging devices other than ink-jet printers, such as devices for discharging fuel, perfume, or the like, devices for applying pressure to liquid medicine or the like, and so forth, as long as the devices use an electrostatic actuator.

[0025] Also, the embodiments are described for illustrative purposes only. Accordingly, one skilled in this art will be able to replace the various components of the examples with equivalents, and such embodiments are also contained within the scope of the present invention.

[First Embodiment]

[0026] Fig. 1 through Fig. 6 illustrate an ink-jet printer provided with an ink-jet head according to a first embodiment of the present invention.

(Overview of the configuration)

[0027] Fig. 1 is a schematic configuration diagram illustrating the overall configuration of the ink-jet printer to which the present invention is applied. The ink-jet printer 300 according to the present example is a common arrangement, having a platen roller 300 serving as a component of transporting means for transporting recording paper 105, an ink-jet head 1 facing the platen roller 300, a carriage 302 for reciprocally moving this ink-jet head 1 in a line direction (scanning direction) which is the axial direction of the platen roller 300, and an ink tank 301 for supplying ink to the ink-jet head 1 via an ink tube 306.

[0028] Reference numeral 303 denotes a pump, which is used in the event that a state of detective ink discharge occurs at the ink-jet head 1, for sucking the ink via a cap 304 and waste ink tube 308 to a waste ink container 305.

(Ink-jet head)

[0029] Fig. 2 is an exploded perspective view of the ink-jet head of the present example, Fig. 3 is a schematic longitudinal cross-sectional diagram of the assembled ink-jet head, Fig. 4 is a schematic lateral cross-sectional diagram thereof, and Fig. 5 is an explanatory diagram illustrating the electrode position of the ink-jet head.

[0030] As is shown in these Figures, the ink-jet head 1 is a face type electrostatic ink-jet head wherein ink droplets are discharged from ink nozzles provided on the upper face of a substrate. This ink-jet head 1 is formed of a three-layer structure comprising an upper nozzle plate 2 and a lower glass substrate 4 having a cavity plate 3 sandwiched therebetween.

[0031] The cavity plate 3 is a silicon substrate for example. In the surface of this plate are formed by etching: a recesses 7 for pressure chambers 6 whose bottoms function as vibrating plates 5, fine grooves 9 for ink supply openings 8 provided at the rear portion of each recess 7, and a recess 11 for a common ink chamber 10 for supplying ink to each of the pressure chambers 6.

[0032] In addition, a recess 13 for an atmospheric pressure chamber 12 communicating with the atmosphere is formed by etching at a position adjacent to the pressure chamber recess 7 positioned at the far edge. The bottom portion of this atmospheric pressure chamber 12 functions as a displacement plate 16 which is displaced according to changes in the external atmospheric pressure. In the present embodiment, the compliance of this displacement plate 16 is set so as to be 10,000 or more times the total sum of the compliances of the vibrating plates 5.

[0033] A groove 15 for a communication hole 14 for the atmospheric pressure chamber 12 to communicate with the external atmosphere is also formed. The lower face of the cavity plate 3 is smoothed by mirror polishing.

[0034] The nozzle plate 2 joined to the upper face of the cavity plate 3 is a silicon substrate for example, like the cavity plate 3. In the nozzle plate 2, plural ink nozzles 21 respectively communicating with the pressure chambers 6 are formed at the portions respectively defining the top walls of the respective pressure chambers 6. An ink supply hole 22 for supplying ink to the common ink chamber 10 is formed in the portion defining the top wall of the common ink chamber 10.

[0035] Joining the nozzle plate 2 to the cavity plate 3 causes the above recesses 7, 11, 13, and fine grooves 9 and 15 to be covered, and the pressure chambers 6, ink supply openings 8, common ink chamber 10, pressure compensating chamber 12, and communication hole 14 to be formed and separated from one another.

[0036] The ink supply hole 22 is connected to the ink tank 301 (see Fig. 1) via the connecting pipe 23 and a tube 306 (see Fig. 1). The ink supplied through the ink supply hole 22 is supplied to the independent pressure chambers 6 via the ink supply openings 8.

[0037] The glass substrate 4 joined to the lower face of the cavity plate 3 is a borosilicate glass substrate, which has a thermal expansion coefficient close to that of silicon. In the glass substrate 4, recesses 42 for vibrating chambers (sealed chambers) 41 are formed at the portions facing the vibrating plates 5. Individual

electrodes 43 corresponding to the vibrating plates 5 are respectively formed at the bottoms of the recesses 42. The individual electrodes 43 each have a segment electrode 44 formed of ITO and a terminal portion 45.

[0038] A recess 46 of the same depth as the recesses 42 is farmed in the glass substrate 4 at the portion facing the displacement plate 16, which forms the bottom portion of the atmospheric pressure chamber 12, with the recess 46 being connected to the recesses 42 via a communication recess 47. A dummy electrode 48 of ITO is formed on the bottom of the recess 46 is well.

[0039] Joining the glass substrate 4 to the cavity plate 3 causes the vibrating plates 5 defining the bottoms of the pressure chambers 6 and the respective segment electrode portions 44 of the individual electrodes 43 to face each other across an extremely narrow gap G. This gap G is sealed by a sealing agent 20 placed between the cavity plate 3 and the glass substrate 4, and a sealed vibrating chamber 41 is formed. Also, the recess 46 is covered by the displacement plate 16 which is the bottom portion of the atmospheric pressure chamber 12, thereby forming the pressure compensating chamber 49 for changing the pressure of the vibrating chambers 41 according to fluctuations in the external atmospheric pressure. The pressure compensating chamber 49 communicates with the vibrating chambers 41 via the communication portion 50 formed by the communication recess 47.

[0040] Each of the vibrating plates 5 is formed thin and is capable of elastic deformation in the direction perpendicular to its plane, i.e., the vertical direction in Fig. 3. The vibrating plate 5 functions as a common electrode on the side of the pressure chambers. The vibrating plate 5 and the corresponding segment electrode 44 form electrodes that face each other across the gap G.

[0041] A head driver 220 (Fig. 6), described below, is connected to the vibrating plates 5 and the individual electrodes 43. Outputs of the head driver 220 are respectively connected to the terminals 45 of the individual electrodes 43, and another output is connected to the common electrode terminal 26 formed at the cavity plate 3. The cavity plate itself has electro-conductivity, so the vibrating plates 5 take the potential of the common electrode terminal 26. Incidentally, in the event that there is a need to reduce the electric resistance between the common electrode terminal 26 and the vibrating plates 5, a thin film of an electrically conductive material such as gold or the like may be formed on one face of the cavity plate 3 by vapor deposition, sputtering, or the like. With the present example, anodic bonding is used for joining the cavity plate 3 and the glass substrate 4, so an electrically conductive film is formed on the side where the channels are formed in the cavity plate 3. The dummy electrode 48 is for preventing the displacement plate 16 from adhering to the glass substrate at the time of anodic bonding.

(Pressure compensating operation)

[0042] With the ink-jet head 1 of this configuration, applying a driving voltage across a pair of opposing electrodes from the head driver 220 generates electrostatic force due to charges that accumulate on the opposing electrodes, the vibrating plate 5 warps toward the side of the segment electrode portion 44, and the volume of the pressure chamber 6 increases. Next, canceling the driving voltage from the head driver 220 between the opposing electrodes and discharging them causes the vibrating plate to return by means of its elastic restoring force, and the volume of the pressure chamber 6 rapidly shrinks. Due to the internal pressure change generated at this time, a portion of ink in the pressure chamber 6 is discharged from the ink nozzle 21 communicating with the pressure chamber 6 so as to be discharged toward recording paper.

[0043] Now, a case where the external atmospheric pressure changes will be described. For example, in the event that the device is moved from sea level to a high altitude, the external atmospheric pressure drops. In this case, unless the internal pressure of the vibrating chambers 41 also changes, this internal pressure becomes markedly greater than the external atmospheric pressure. Consequently, in order to obtain a balanced state of pressure, the vibrating plate 5 of each vibrating chamber 41 warps upwards as viewed in Fig. 4, so that the volume of the vibrating chambers 41 is increased.

[0044] However, with the present example, the vibrating chambers 41 communicate with the pressure compensating chamber 49 via the communication portion 50. This pressure compensating chamber 48 adjoins the atmospheric pressure chamber 12 communicating with the atmosphere, with the displacement plate 16 in between. The compliance of the displacement plate 16 is extremely great as compared to that of the vibrating plates 5. Accordingly, the displacement plate 16 is displaced upwards in Fig. 4 before the vibrating plates 5 are displaced, thereby increasing the volume of the pressure compensating chamber 49, and forming a balanced state of pressure with the external atmospheric pressure. Accordingly, the gap between the vibrating plates 5 and the associated individual electrode 43 is maintained at a constant value, regardless of fluctuations in external pressure.

[0045] As described above, with the ink-jet head 1 according to the present example, even in the event that fluctuations in the external atmospheric pressure occur, there are essentially no adverse effects on the vibrating properties of the vibrating plates. Accordingly, continuously stable ink discharging properties can be obtained, regardless of fluctuations in the external atmospheric pressure.

[0046] Incidentally, with the ink-jet head according to the present example, the vibrating chambers 41 and pressure compensating chamber 49 are formed side by

side. That is, at the time of forming the recessions 7 for the pressure chambers in the cavity plate 3, i.e., at the time of forming the vibrating plates 5, the displacement plate 16 is also formed to a thickness approximately the same as that of the vibrating plates 5. Accordingly, manufacturing of an ink-jet head having pressure compensating functions is easy. Also, the displacement plate 16 is covered by the nozzle plate 2, and thus it is advantageous in that this portion can be securely protected so that there is no damage it. Further, such a protecting portion uses a portion of the nozzle plate 2, and thus is advantageous in that manufacturing is easier than in a case using a separate protective plate.

(Control system)

[0047] Incidentally, Fig. 6 is a schematic diagram of the control system of the ink-jet printer 300 according to the present example. The circuit portion comprising the center of this control system can be formed with a one-chip micro-computer, for example. Briefly describing the overview of the control system according to the present example with reference to the Figures, reference numeral 201 denotes a printer control circuit, and RAM 205, ROM 206, and character generator ROM (CG-ROM) 207 are connected to this printer control circuit 201 via internal busses 202, 203, and 204, including an address bus and a data bus.

[0048] A control program is stored in ROM 206, and the drive control action of the ink-jet head 1 is executed based on the control program called and activated therefrom. RAM 205 is used as the working memory for the drive control, and dot patterns corresponding to input characters are rendered in the CG-ROM 207.

[0049] Reference numeral 210 denotes a head drive control circuit, which outputs driving signals, clock signals, etc., to the head driver 220, under the control of the printer control circuit 201 which is connected via the internal bus 209. Also, printing data DATA is provided via the data bus 211.

[0050] The head driver 220 is comprised of a TTL array for example, which generates driving voltage pulses corresponding to input driving signals, applies these to the individual electrodes 43 and the common electrode 26 which are the object of driving, so as to cause discharge of ink droplets from the corresponding ink nozzles 21. In order to generate the driving voltage pulses, ground voltage GND, driving voltage Vn, etc., are supplied to the head driver 220. These voltages are generated from the driving voltage Vcc of the power source circuit 230.

[0051] A carriage motor drive control circuit 232 is connected to the printer control circuit 201 via the internal bus 231. The carriage motor drive control circuit 232 drives the carriage motor (not shown) for reciprocally moving the carriage 302 carrying the ink-jet head 1 via a motor driver 233, so as to move the ink-jet head 1 in the direction shown by the arrow 234 in the Figure. A transport motor drive control circuit 242 is connected to the printer control circuit 201 via the internal bus 241. The transport motor drive control circuit 242 drives a transport motor via a motor driver 243, and performs transport control of recording paper 105 following the platen roller 300, in the transporting direction shown by the arrow 244 in the Figure.

[Second Embodiment]

[0052] The displacement plate 16 for pressure compensation in the above ink-jet head 1 may be formed so as to be in the form of a curved plane under standard external atmospheric pressure at sea level, instead of a flat plate form, us described next.

[0053] Fig. 7 is a partial cross-sectional diagram of an ink-jet head 1A having the displacement plate 16A of a curved form which is bent toward the side of the atmospheric pressure chamber 12 in a protruding manner. The members other than this displacement plate 16A are the same as those in the ink-jet head 1 shown In Fig. 2 through Fig. 5.

[0054] The displacement plate 16A with such a form can be manufactured as follows. A boron-doped layer of silicon is formed by doping boron into the portion in which the displacement plate 16A is to be formed, before etching the cavity plate 3. The boron-doped layer is etched at the same time as performing etching for forming the vibrating plates 5, thereby forming the displacement plate 16A.

[0055] Boron is dispersed in the boron-doped layer portion, and thus is expanded as compared to other silicon portions. Further, the expansion of the portion where the boron-doped layer is formed is restricted by the silicon portions at both sides thereof which have not been doped with boron. Accordingly, forming a thin displacement plate 16A at the boron-doped layer portion causes the displacement plate 16A to be a curved form that is bent in a protruding form in the outer direction, or in a recessed form.

[0056] A glass substrate 4 is joined by anodic bonding to the lower face of the cavity plate 3 in which the displacement plate 16A is formed, and a sealed pressure compensating chamber 49 is sectioned and formed by the displacement plate 16A and the opposing glass substrate portion. The opposite side of the displacement plate 16A faces the atmospheric pressure chamber 12. Accordingly, as shown in Fig. 7, the displacement plate 16A projects in a protruding curved plane form toward the side of the atmospheric pressure chamber 12.

[0057] With the ink-jet head 1A having the displacement plate 16A protruding in a curved plane form toward the side of the atmospheric pressure chamber 12 as described above, in the event that the external atmospheric pressure is high, the displacement plate 16A is pressed toward the side of the pressure compensating chamber 49 and warps. Accordingly, the atmospheric pressure fluctuations can more effectively

compensated for in the event that the external atmospheric pressure is high, as compared with the flat displacement plate 16.

[0058] However, such a displacement plate 16A which protrudes toward the side of the atmospheric pressure chamber must warp even further in the protruding direction in the event that the external atmospheric pressure is lower than the internal pressure of the pressure compensating chamber 49 (the atmospheric pressure at the time of sealing this chamber 49), so the compliance drops. Accordingly, the pressure compensating functions thereof may not be sufficiently exhibited.

[0059] Fig. 8 is a graph illustrating a characteristic curve qualitatively illustrating how the compliance of the displacement plate 16A changes with the external atmospheric pressure. In this graph, the horizontal axis indicates the external atmospheric pressure, and the vertical axis indicates the compliance. As can be understood from this graph, the lower the external atmospheric pressure compared to the air pressure at the time of sealing the pressure compensating chamber 49, the lower the compliance of the displacement plate 16A, and this rapidly deteriorates in a non-linear form. That is, with lower pressure the displacement plate 16A does not warp as readily, and accordingly, its pressure compensating functions deteriorate rapidly.

[0060] In the event that the external atmospheric pressure is low, in order to sufficiently raise the compliance of the displacement plate 16A so as to be sufficiently high even at high elevations for example, the pressure compensating chamber 49 is preferably sealed at reduced pressure. For example, the pressure compensating chamber 49 is preferably sealed at a reduced pressure state of around 650 hPa ± 50 hPa absolute pressure.

[0061] Fig. 9 is an explanatory diagram illustrating the behavior of the displacement plate 16A sealed at a reduced pressure. In The Figure, the solid line represents the state of the displacement plate 16A before airtight sealing, the dotted line represents the state of the displacement plate 16A after reduced-pressure sealing, and the broken line represents the state of the displacement plate 16A in the event that the external atmospheric pressure is high.

[0062] Thus, even in the event that the external atmospheric pressure is high, the displacement plate 16A does not come into contact with the bottom of the pressure compensating chamber 49 (the surface of the dummy electrode 48) and does not stop functioning. As can be understood from the graph in Fig. 8, the compliance of the displacement plate 16A relative to fluctuations in the external atmospheric pressure is maintained in an almost linear relationship, so compensation according to fluctuations in the external atmospheric pressure can be performed in a secure manner.

[Third Embodiment]

[0063] Fig. 10 is a schematic cross-sectional diagram illustrating a third embodiment of the ink-jet head to which the present invention is applied, and Fig. 11 is an explanatory diagram illustrating the positional relationship between the vibrating chambers and the pressure compensating chamber. The basic structure of the ink-jet head 1B according to the present embodiment is the same as that of the above-described ink-jet heads 1 and 1A, with a structure wherein a nozzle plate 2B is bonded to the upper face and a glass substrate 4B is bonded to the lower face of a cavity plate 3B which is thus sandwiched between the two.

[0064] Pressure chambers 6B respectively communicating with ink nozzles 21B, and a common ink chamber 10B communicating with the pressure chambers 6B via ink supply chambers 8B, are sectioned and formed by the nozzle plate 2B together with the cavity plate 3B. Also, an atmospheric pressure chamber 12B is sectioned and formed at a position adjacent to the common ink chamber 10B, and this atmospheric pressure chamber 12B communicates with the atmosphere via a communication hole 14B.

[0065] A thin displacement plate 16B is formed at the bottom portion of the atmospheric pressure chamber 12B, and vibrating plates 5B are formed at the bottom portions of the pressure chambers 6B. Vibrating chambers 41B each having a gap for allowing the corresponding vibrating plate 5B to be displaced, and a pressure compensating chamber 49B having a gap for allowing the displacement plate 16B to be displaced are sectioned and formed by the lower face of the cavity plate 3B together with the glass substrate 4B. The pressure compensating chamber 49B communicates with the vibrating chambers 41B. Individual electrodes 43B formed of ITO are respectively formed on the bottoms of vibrating chambers 41B, and a dummy electrode 48B formed of ITO is formed on the bottom of the pressure compensating chamber 49B.

[0066] The portion of the nozzle plate 2B forming a wall portion of the common ink chamber 10B is a displacement plate 10A capable of being displaced in the direction perpendicular to its plane. This displacement plate 10A is for preventing pressure fluctuations in the pressure chambers 6B from carrying over to the neighboring pressure chambers 6B via the common ink chamber 10B, and is displaced by elasticity in the direction perpendicular to its plane, according to pressure fluctuations.

[0067] With the ink-jet heed 1B according to the present embodiment as well, the displacement plate 16B sectioning the pressure compensating chamber 49B is displaced according to fluctuations in the external atmospheric pressure. Accordingly, the vibrating plates 5B are prevented from being displaced according to fluctuations in the external atmospheric pressure, so that stable ink ejecting properties can be maintained.

[0068] Incidentally, a configuration employing a plurality of atmospheric pressure chambers 12B and pressure compensating chambers 49B may be used. Fig. 12 shows an example wherein two atmospheric pressure chambers and two corresponding pressure compensating chambers are used, wherein two displacement plates are positioned accordingly.

[0069] Fig. 13 illustrates an improved example of the ink-jet head 1B. With this ink-jet head 1C as well, a nozzle plate 2C and a glass substrate 4C are provided on top of end below a cavity plate 3C, respectively. Ink nozzles 21C are formed in the nozzle plate 2C. Pressure chambers 6C respectively communicating with the nozzles 21C and a common ink chamber 10B communicating with the pressure chambers 6C via ink supply chambers 8C are sectioned and formed by the nozzle plate 2C together with the cavity plate 3C.

[0070] Vibrating plates 5C are formed at the bottom portions of the pressure chambers 6C. A displacement plate 16C having a compliance far greater than that of the vibrating plates 5C is provided on the bottom portion of the common ink chamber 10C. Vibrating chambers 41C each having a gap for allowing the corresponding vibrating plate 5C to be displaced, and a pressure compensating chamber 49C having a gap for allowing the displacement plate 16C to be displaced are sectioned and formed by the lower face of the cavity plate 3C together with the glass substrate 4C. The pressure compensating chamber 49C communicates with the vibrating chambers 41C. Individual electrodes 43C formed of ITO are respectively formed on the bottoms of the vibrating chambers 41C, and a dummy electrode 48C formed of ITO is formed on the bottom of the pressure compensating chamber 49C.

[0071] With the ink-jet head 1C according to the present example, displacement plate 16C is formed as the bottom of the common ink chamber 10C. Accordingly, the displacement plate 16C functions as both the displacement plate 16B and the displacement plate 10A of the above-described ink-jet head 1B. That is to say, this displacement plate 16C prevents pressure fluctuations in the pressure chambers 6C from carrying over to the neighboring pressure chambers 6C via the common ink chamber 10C. Also, the vibrating plates 5C are prevented from being displaced according to fluctuations in the external atmospheric pressure, so that stable ink ejecting properties can be maintained.

[0072] The ink-jot head 1C according to the present example can be formed in a more compact manner than the above-described ink-jet head 1B. That is, there is no need to provide a separate atmospheric pressure chamber, and the initial atmospheric fluctuation compensation and internal pressure fluctuations within the common ink chamber are absorbed by the single displacement plate 16C.

[Fourth Embodiment]

[0073] Fig. 14 (A) is a partial cross-sectional diagram illustrating a fourth embodiment of the ink-jet head to which the present invention is applied, and Fig. 14 (B) is an explanatory diagram illustrating the positional relationship between the vibrating chambers and the pressure compensating chamber. This ink-jet head 1D is also configured with a nozzle plate 2D and a glass substrate 4D being provided on top of and below a cavity plate 3D, respectively. Ink nozzles 21D are formed in the nozzle plate 2D. Pressure chambers 6D respectively communicating with the nozzles 21D, a common ink chamber 10D communicating with the pressure chambers 6D via ink supply chambers 8D, and an atmospheric pressure chamber 12D communicating with the atmosphere, are sectioned and formed by the nozzle plate 2D together with the cavity plate 3D. Vibrating plates 5D are formed at the bottom portions of the pressure chambers 6D. A displacement plate 16D1 is formed at the bottom portion of the common ink chamber 10D. In the same ways a displacement plate 16D2 is formed at the bottom portion of the atmospheric pressure chamber 12D.

[0074] Vibrating chambers 41D each having a gap for allowing the corresponding vibrating plate 5C to be displaced, and a first pressure compensating chamber 49D1 having a gap for allowing the displacement plate 16D1 to be displaced, and a second pressure compensating chamber 49D2 having a gap for allowing the displacement plate 16D2 to be displaced, are sectioned and formed by the lower face of the cavity plate 3D together with the glass substrate 4D. The pressure compensating chamber 49D1 communicates with the vibrating chambers 41D, and the pressure compensating chamber 49D2 communicates with the pressure compensating chamber 49D1.

[0075] Individual electrodes 43D formed of ITO are respectively formed on the bottoms of the vibrating chambers 41D, and electrodes 48D1 and 48D2 formed of ITO are respectively formed on the bottoms of the pressure compensating chambers 49D1 and D2.

[0076] As shown in Fig. 15(A), applying voltage across the displacement plate 16D1 and the electrode 48D1 generates electrostatic attractive force, whereby the displacement plate 16D1 is drawn toward the electrode side and is warped. Consequently, the volume of the first pressure compensating chamber 49D1 is reduced, and the internal pressure of the communicating vibrating chambers 41D is increased. Stopping application of the voltage causes elastic restoring of the displacement plate 16D1, so the internal pressure of the communicating vibrating chamber 41D also returns to the original state.

[0077] For example, in the event that the ambient atmospheric pressure has a certain value, voltage is applied between the displacement plate 16D1 and the electrode 48D1 so that the displacement plate 16D1 is

drawn toward the electrode 48D1, as shown in Fig 15 (B). In the event that the external atmospheric pressure drops, lowering the applied voltage or flopping the voltage application causes the internal pressure of the vibrating chambers 41D to drop, so the pressure difference with the external atmospheric pressure decreases. Accordingly, the vibrating properties of the vibrating plates 5D can be held constant, and a change in the ink discharge properties can be suppressed.

[0078] On the other hand, in the event that the external atmospheric pressure increases, raising the applied voltage causes the warping of the displacement plate 16D1 to increase, and the pressure in the vibrating chambers 41D to be raised, so the pressure difference with the external atmospheric pressure can be reduced, and a change in the ink discharge properties can be suppressed in this case, as well.

[0079] In the event that the amount of change in the external atmospheric pressure is great, a volume change of the second pressure compensating chamber 12D2 can be used as follows. That is, in the event that the ambient atmospheric pressure has a certain value, a voltage is applied between the displacement plate 16D1 and the electrode 48D1 so that the displacement plate 16D1 is in a state of being drawn toward the electrode 48D1, as shown in Fig 15 (A). In the event that the external atmospheric pressure rises, a voltage is also applied across the second displacement plate 16D2 and the electrode 48D2 so that the displacement plate 16D2 is also warped. Consequently, the capacity of the second pressure compensating chamber 12D2 also is reduced, so the pressure of the vibrating chambers 41D can be greatly increased to match the rise in the external atmospheric pressure. Accordingly, the pressure difference between the external atmospheric pressure which has risen greatly and the internal pressure of the vibrating chambers can be reduced or own made zero.

[0080] Conversely, in the event that the external atmospheric pressure drops, application of voltage is stopped, so that the first displacement plate 16D1 returns to the original state, thereby increasing the volume of the first pressure compensating chamber 49D1. Accordingly, the internal pressure of the vibrating chambers 41D drops, and the pressure difference between the external atmospheric pressure and the internal pressure is reduced or made zero. The voltage application control for the electrodes 48D1 and 48D2 for increasing or decreasing the volume of the first and second pressure compensating chamber 12D1 and 12D2 can be performed by a control mechanism such that described below.

[0081] That is, as shown in Fig. 16, the external atmospheric pressure is detected by air pressure detecting means 401, a set air pressure is compared with the detected external atmospheric pressure by pressure comparing means 402, and the displacement plates 16D1 and 16D2 are displaced by displacement plate driving means 403, based on the comparison result.

[0082] Incidentally, various sensors can be used for the air pressure detecting means, such as electrostatic capacity air pressure sensors, piezoelectric air pressure sensors, and so forth. Also, the mounting position of the air pressure detecting means is not restricted to near the ink-jet head 1D, but rather may be at any position where similar air pressure measurement can be performed.

[0083] Also, the external atmospheric pressure may be calculated by detecting the electrical capacity between the displacement plate and the electrode.

[Fifth Embodiment]

[0084] Fig. 17 is a partial configuration diagram illustrating the principal components of a fifth embodiment of the ink-jet head to which the present embodiment is applied. The basic structure of the ink-jet head 1E according to the present embodiment is the same as that of the above-described embodiments, with a nozzle plate 2E end glass substrate 4E being laid on top and below a cavity plate 3E which is thus sandwiched in between the two. Ink nozzles 21E are formed in the nozzle plate 2E. Pressure chambers 6E respectively communicating with the nozzles 21E and a common ink chamber 10E communicating with the pressure chambers 6E via ink supply chambers 8E are sectioned and formed by the nozzle plate 2E together with the cavity plate 3E. Vibrating plates 5E are formed at the bottom portions of the pressure chambers 6E.

[0085] Vibrating chambers 41E each having a gap for allowing the respective vibrating plate 5E to be displaced are sectioned and formed by the lower face of the cavity plate 3E together with the glass substrate 4E. Individual electrodes 43E formed of ITO are formed on the bottom of the vibrating chambers 41E.

[0086] The present embodiment is characterized in that instead of providing a pressure compensating chamber whose volume changes according to a displacement plate as the pressure compensating means, a heat controlling member 160 is used to heat or chill a gas sealed in the vibrating chambers 41E, thereby increasing or reducing the internal pressure of the vibrating chambers 41E, and consequently reducing the pressure difference with the external atmospheric pressure or making it zero.

[0087] As is known from Boyle-Charles' law, air pressure can be controlled by heat. For example, in the event that the external atmospheric pressure increases, the heat controlling member 160 is made to generate heat, and heating the vibrating chamber formation portions of the glass substrate 4E heats the gas within the vibrating chambers which attempts to expand. However, the vibrating chambers 41E are sealed, so the internal pressure increases, and the pressure difference with the external atmospheric pressure is relieved.

[0088] Conversely, in the event that the external

atmospheric pressure drops, the heat controlling member 160 performs an endothermic or chilling action, thereby cooling the glass substrate 4E, which cools the gas within the vibrating chambers, thus lowering their internal pressure. Accordingly, the pressure difference with the external atmospheric pressure can be relieved.

[0089] The heat controlling member may be a heat-generating member such as a tantalum nitride thin film, for example. Alternatively, this may be such which is capable of endothermic action, such as a Peltier element.

[0090] Fig. 18 is a schematic diagram of the drive control arrangement for the heat controlling member. As shown in the Figure, air pressure detecting means 501 detects the external atmospheric pressure. The detected external atmospheric pressure is converted into the internal temperature of the vibrating chamber 41E, in air pressure/temperature converting means 502. The converted temperature is compared with a preset target temperature in the temperature comparing means 503. The heat controlling member driving means 504 drives the heat controlling member 160 based on the comparison results, such that the temperature within the vibrating chamber is the target temperature.

[0091] Incidentally, temperature detecting means 505 may be attached to the glass substrate 4E (see Fig. 17), comparing the detected value with the target temperature in order to execute even more precise temperature management.

[0092] Also, detection of the air pressure may be obtained by calculation based on the electrostatic capacity between the vibrating plate 5E and electrode 43E in the vibrating chamber 41E, instead of mounting an air pressure sensor or the like on the ink-let printer.

[0093] In this case, as shown in Fig. 19, the electrostatic capacity between the vibrating plate and electrode is detected by electrical capacity detecting means 601, and the detected capacity is compared with a preset target value by comparing means 602, so that the heat generating member can be driven and controlled by heat controlling member driving means 603, based on the comparison results.

[Other Embodiments]

[0094] Incidentally, with the above-described embodiments, a displacement plate is formed at one portion of the pressure compensating chamber, so that the volume of the pressure compensating chamber increases or decreases by the displacement plate being displaced according to fluctuations in the external atmospheric pressure. Instead of this, an arrangement may be used wherein the entire pressure compensating chamber 701 is formed of an elastic material, as shown in Fig. 20, so that it expands or contracts in its entirety according to fluctuations in the external atmospheric pressure.

Industrial Applicability

[0095] As described above, the electrostatic actuator according to the present invention has pressure compensating means for reducing or eliminating a pressure difference between the internal pressure of vibrating chambers partitioned by vibrating plates and the external atmospheric pressure, so the vibrating properties of the vibrating plates do not change according to fluctuations in the external atmospheric pressure. Accordingly, a liquid discharging device to which the present invention is applied is capable of constantly performing a stable droplet discharging action, regardless of fluctuations in the external atmospheric pressure. For example, an ink jet printer using the present invention is capable of continuously performing high-quality image formation, regardless of the place of usage, whether at high elevations or at sea level, etc.

Claims

1. An electrostatic actuator, comprising:

    a vibrating plate;
    an electrode plate facing said vibrating plate; and
    a sealed chamber formed between said electrode plate and said vibrating plate;
    wherein said vibrating plate is displaced by electrostatic force, by applying voltage across said vibrating plate and said electrode plate;
    said electrostatic actuator having a pressure compensating means for decreasing the pressure difference between the internal pressure in said sealed chamber and external pressure.

2. An electrostatic actuator according to Claim 1, wherein said pressure compensating means comprises a pressure compensating chamber communicating with said sealed chamber and which is capable of increasing/decreasing volume according to external atmospheric pressure.

3. An electrostatic actuator according to Claim 2, wherein a portion of said pressure compensating chamber is defined by a displacement plate displaceable according to external atmospheric pressure.

4. An electrostatic actuator according to Claim 3, wherein said displacement plate is curved into a form so as to protrude in a direction away from the facing inner wall of said pressure compensating chamber.

5. An electrostatic actuator according to Claim 3, wherein an electrode plate faces said displacement plate.

6. An electrostatic actuator according to Claim 3, wherein said vibrating plate and said displacement plate are sectioned and formed by a common semiconductor substrate.

7. An electrostatic actuator according to Claim 3, wherein said displacement plate is formed of a boron-doped layer formed by doping said semiconductor substrate.

8. An electrostatic actuator according to Claim 1. wherein said pressure compensating means has a heat-generating member capable of at least heating gas sealed in said sealed chamber.

9. An electrostatic liquid discharging device, comprising:

a nozzle for discharging droplets;
a pressure chamber communicating with said nozzle and also holding liquid;
a vibrating plate defining a portion of said pressure chamber and capable of vibrating in an outward direction;
an electrode plate facing said vibrating plate; and
a sealed chamber formed between said electrode plate and said vibrating plate;
wherein applying voltage across said vibrating plate and said electrode plate causes said vibrating plate to vibrate due to electrostatic force, thereby providing the liquid in said pressure chamber with pressure fluctuation for discharging droplets;
said electrostatic liquid discharging device having a pressure compensating means for decreasing the pressure difference between the internal pressure in said sealed chamber and external pressure.

10. An electrostatic liquid discharging device according to Claim 9, wherein said pressure compensating means comprises a pressure compensating chamber communicating with said sealed chamber and which is capable of increasing/decreasing volume according to external atmospheric pressure.

11. An electrostatic liquid discharging device according to Claim 10, wherein a portion of said pressure compensating chamber is defined by a displacement plate displaceable according to external atmospheric pressure.

12. An electrostatic liquid discharging device according to Claim 11, wherein said displacement plate is curved into a form so as to protrude in a direction away from the facing inner wall of said pressure compensating chamber.

13. An electrostatic liquid discharging device according to Claim 11, wherein an electrode plate for displacing said displacement plate by electrostatic force according to change in external atmospheric pressure is provided facing said displacement plate, and further comprises an external atmospheric pressure detecting means for detecting external atmospheric pressure. and a control means for driving said displacement plate according to the detected external atmospheric pressure.

14. An electrostatic liquid discharging device according to Claim 9, wherein said pressure compensating means has a heat-generating member capable of at least heating gas sealed in said sealed chamber, and further comprises an external atmospheric pressure detecting means for detecting external atmospheric pressure, and a control means for driving said heat-generating member according to the detected external atmospheric pressure.

15. An electrostatic liquid discharging device according to Claim 13 or Claim 14. wherein said external atmospheric pressure detecting means comprises electrostatic capacity detecting means for detecting the electrostatic capacity between said vibrating plate and said electrode plate, and estimates the external atmospheric pressure based on said detected electrostatic capacity.

16. An electrostatic liquid discharging device according to Claim 11, comprising a common liquid chamber communicating a plurality of said pressure chambers, wherein a portion of said common liquid chamber is defined by a diaphragm displaceable in the direction perpendicular to its plane in order to relieve pressure fluctuation within said common liquid chamber, and wherein said diaphragm and said displacement plate are a common plate.

17. An electrostatic liquid discharging device according to Claim 10, wherein said pressure chamber and said pressure compensating chamber am sectioned and formed by a common semiconductor substrate.

18. An electrostatic liquid discharging device according to Claim 11, wherein said displacement plate is formed of a boron-doped layer formed by doping said semiconductor substrate.

19. An electrostatic liquid discharging device according to Claim 16, wherein said pressure chamber, said common liquid chamber, and said pressure compensating chamber are sectioned and formed by a common semiconductor substrate.

20. A method for manufacturing an electrostatic actua-

tor comprising a vibrating plate, an electrode plate facing said vibrating plate, and a vibrating chamber formed between said electrode plate and said vibrating plate, wherein said vibrating plate is displaced by electrostatic force, by applying voltage between said vibrating plate and said electrode plate, said method comprising:

a process for forming a pressure compensating chamber communicating with said vibrating chamber;
a process for forming a displacement plate at a portion of said pressure compensating chamber, displaceable according to external atmospheric pressure, into a warped form curved so as to protrude in a direction away from the facing inner wall of said pressure compensating chamber; and
a process for shutting off and sealing said pressure compensating chamber from the external atmosphere, along with said vibrating chamber.

21. A method for manufacturing an electrostatic actuator according to Claim 20, wherein said displacement plate is formed of a boron-doped layer formed by doping said semiconductor substrate.

22. A method for manufacturing an electrostatic actuator according to Claim 20 or Claim 21, further comprising a process for adjusting air pressure for sealing said pressure compensating chamber.

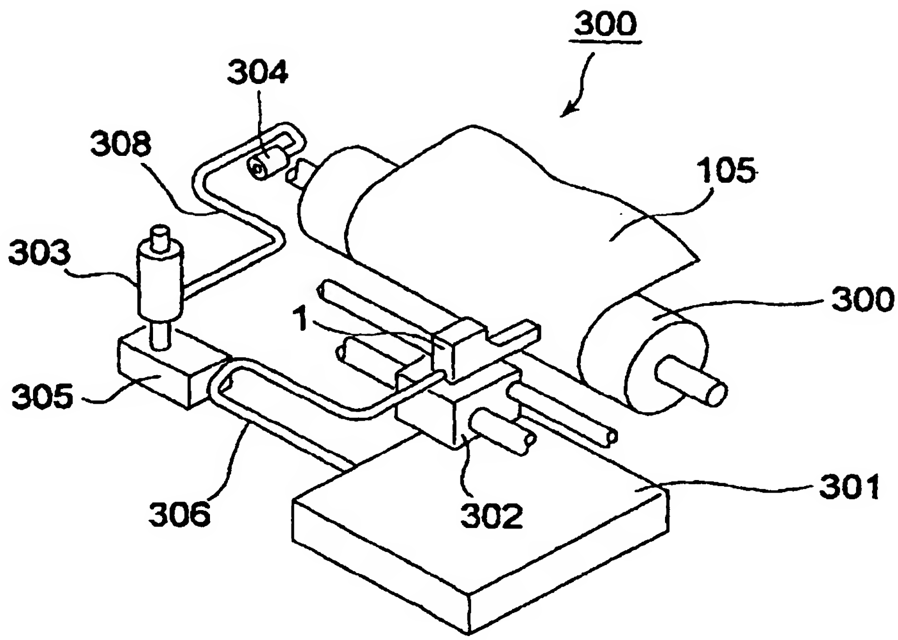
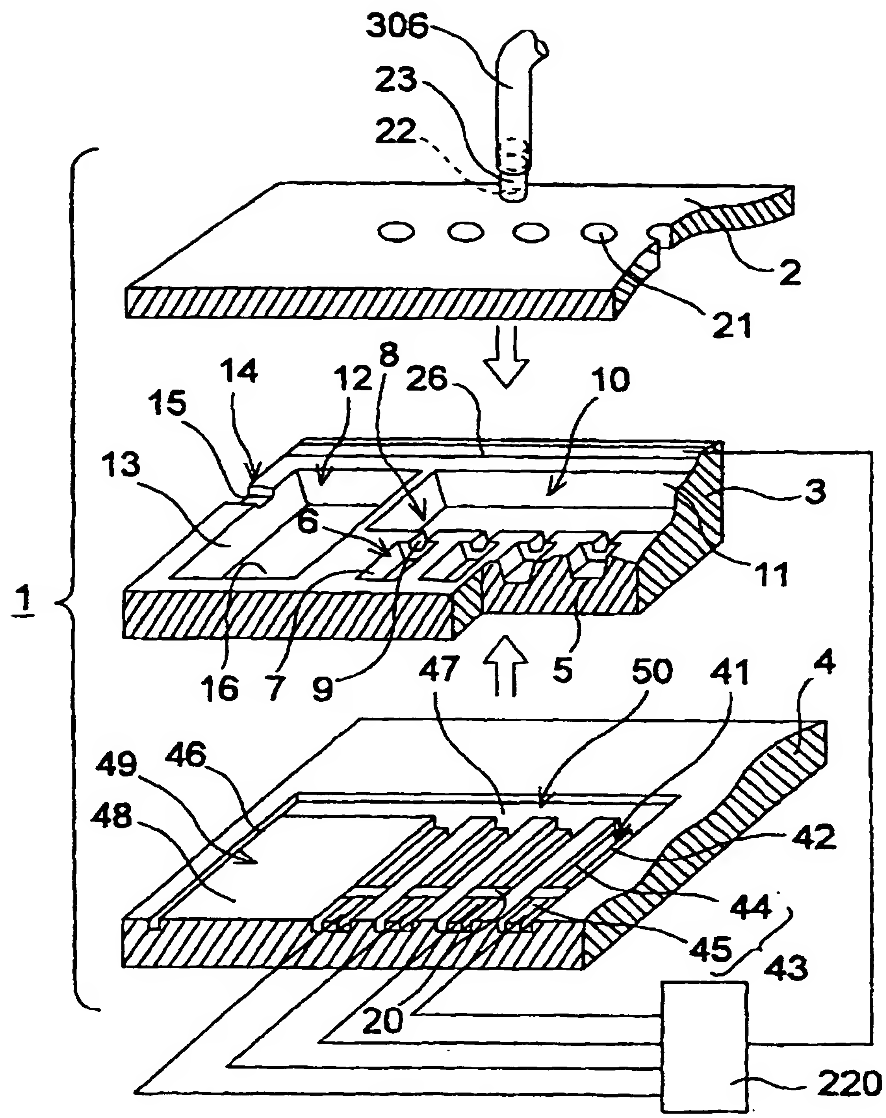


FIG.1



First Embodiment

FIG.2

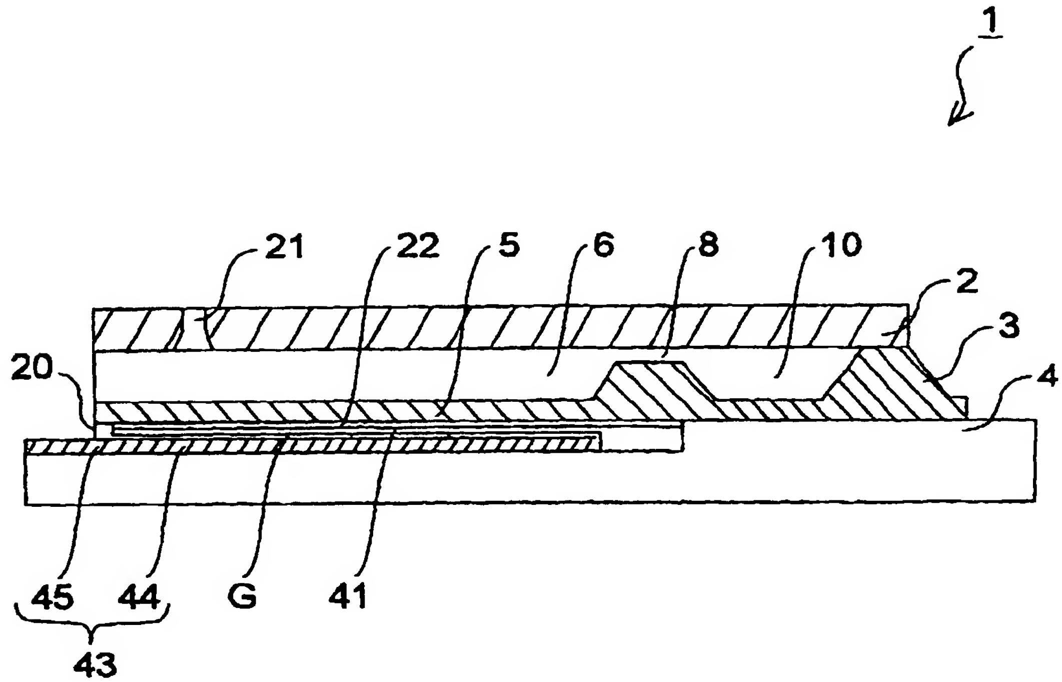


FIG.3

First Embodiment

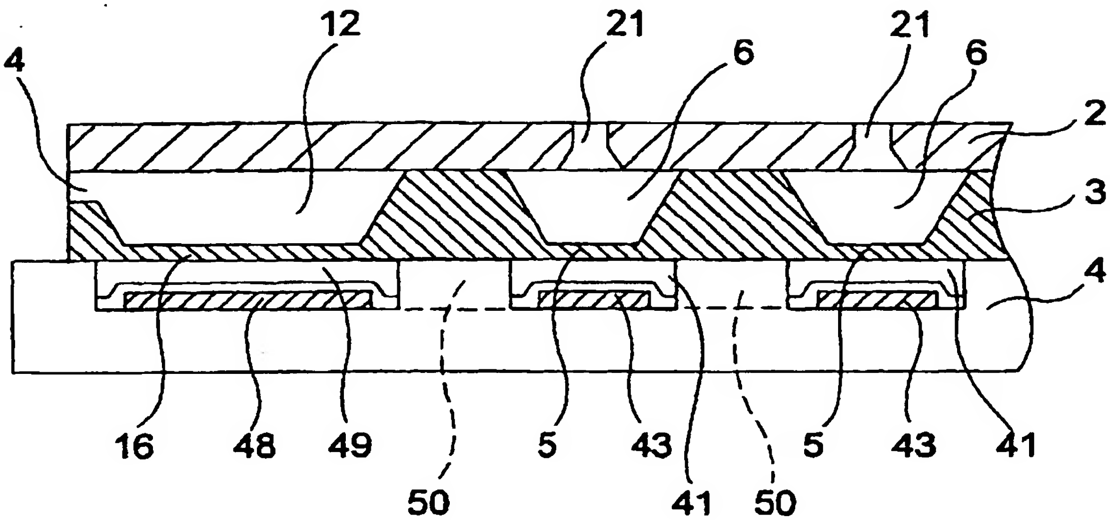


FIG.4

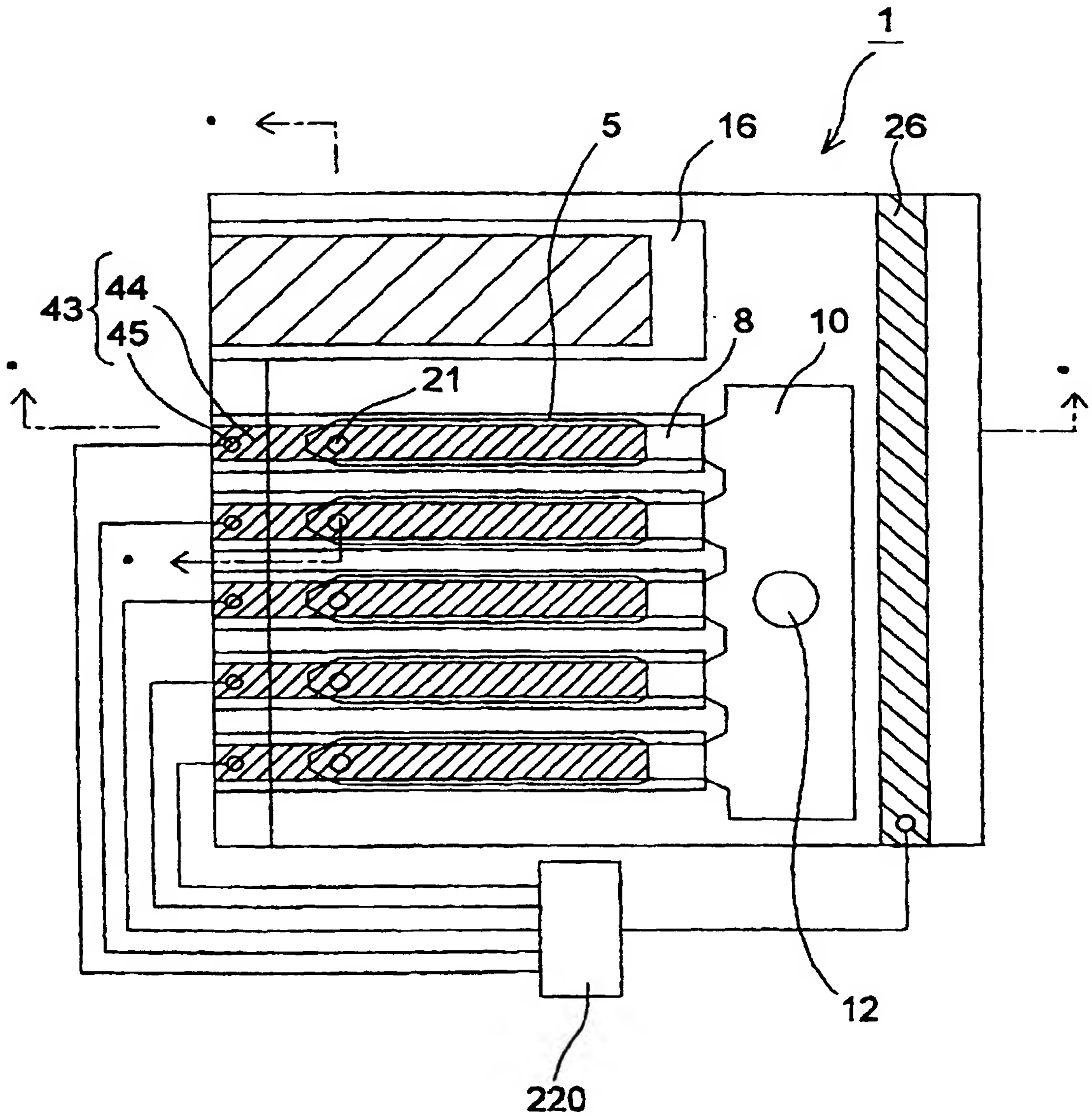
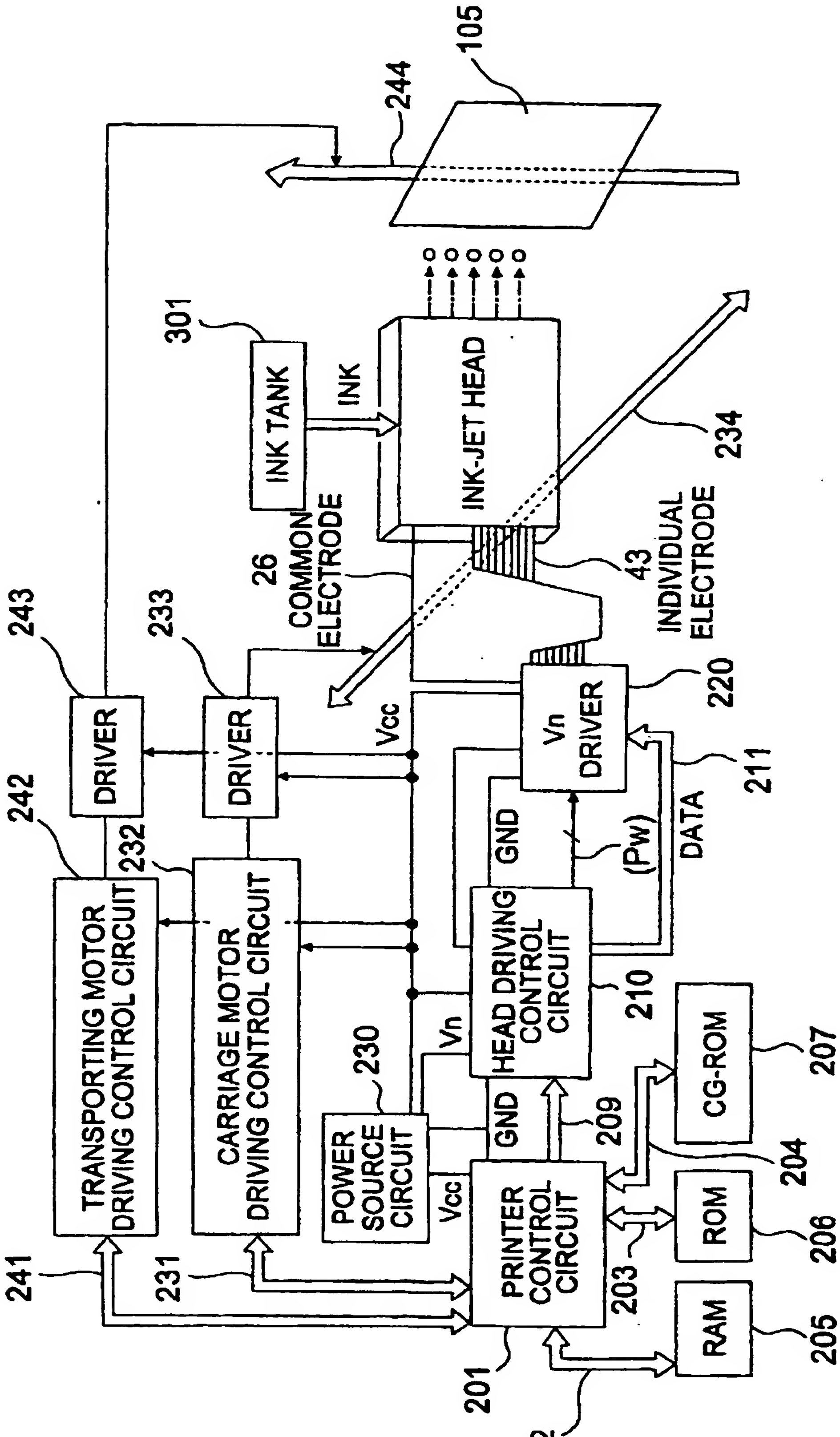


FIG.5



TRANSPORTING MOTOR DRIVING CONTROL CIRCUIT
CARRIAGE MOTOR DRIVING CONTROL CIRCUIT
DRIVER
DRIVER
POWER SOURCE CIRCUIT
PRINTER CONTROL CIRCUIT
HEAD DRIVING CONTROL CIRCUIT
Vn DRIVER
INK TANK
INK
INK-JET HEAD
COMMON ELECTRODE
INDIVIDUAL ELECTRODE
CG-ROM
ROM
RAM
Vcc
Vn
GND
(Pw)
DATA
105
244
243
233
26
301
234
43
220
211
242
232
230
210
209
207
204
206
203
205
241
231
201
202

FIG.6

Second Embodiment

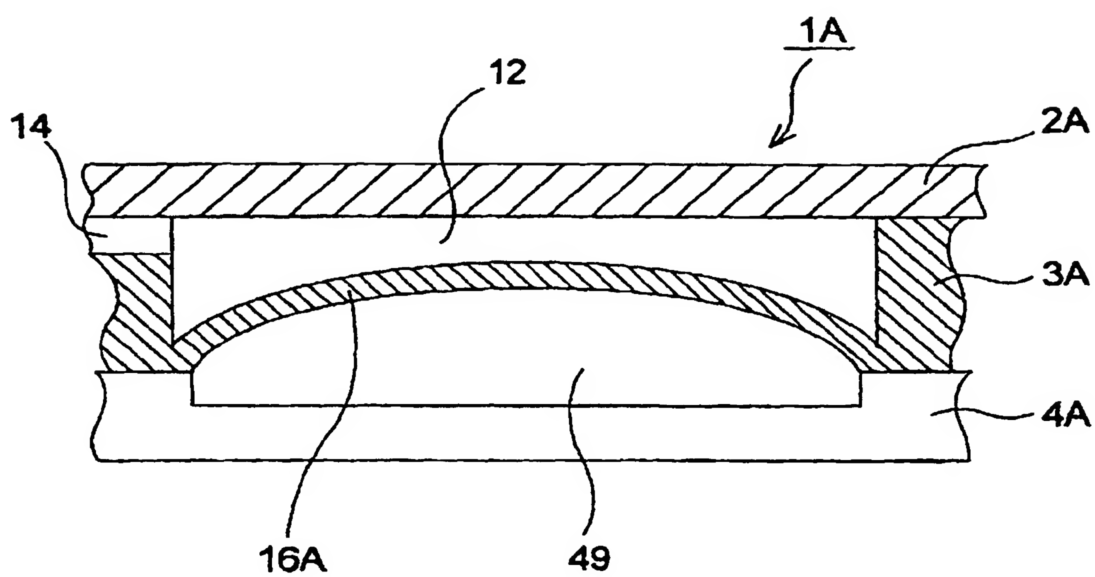


FIG.7

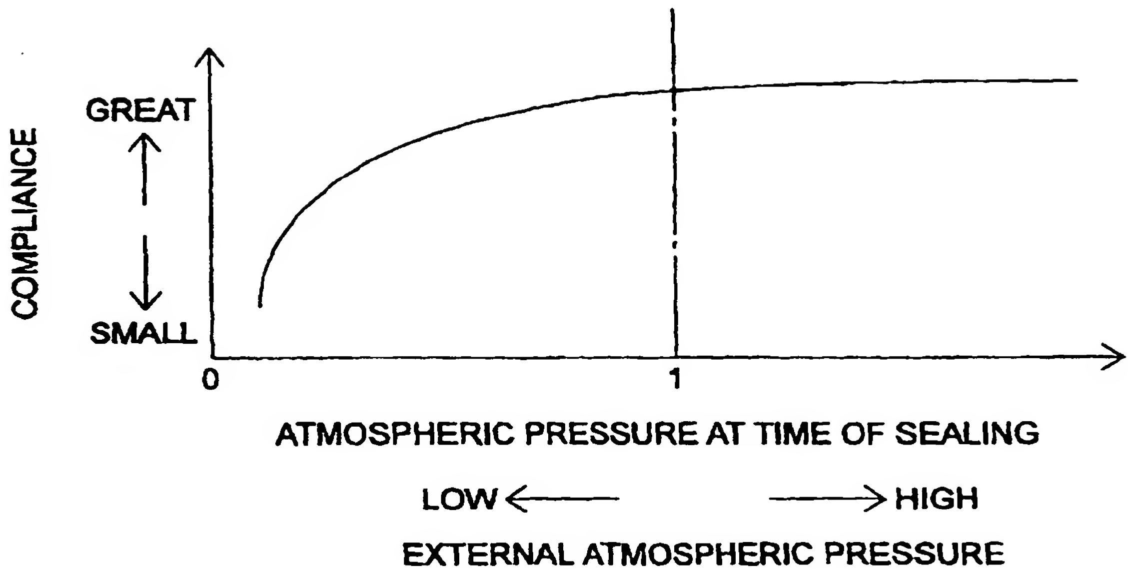

GREAT
COMPLIANCE
SMALL
0
1
ATMOSPHERIC PRESSURE AT TIME OF SEALING
LOW
HIGH
EXTERNAL ATMOSPHERIC PRESSURE

FIG.8

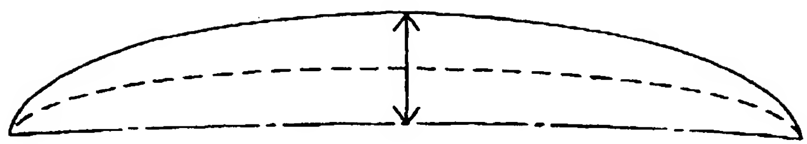
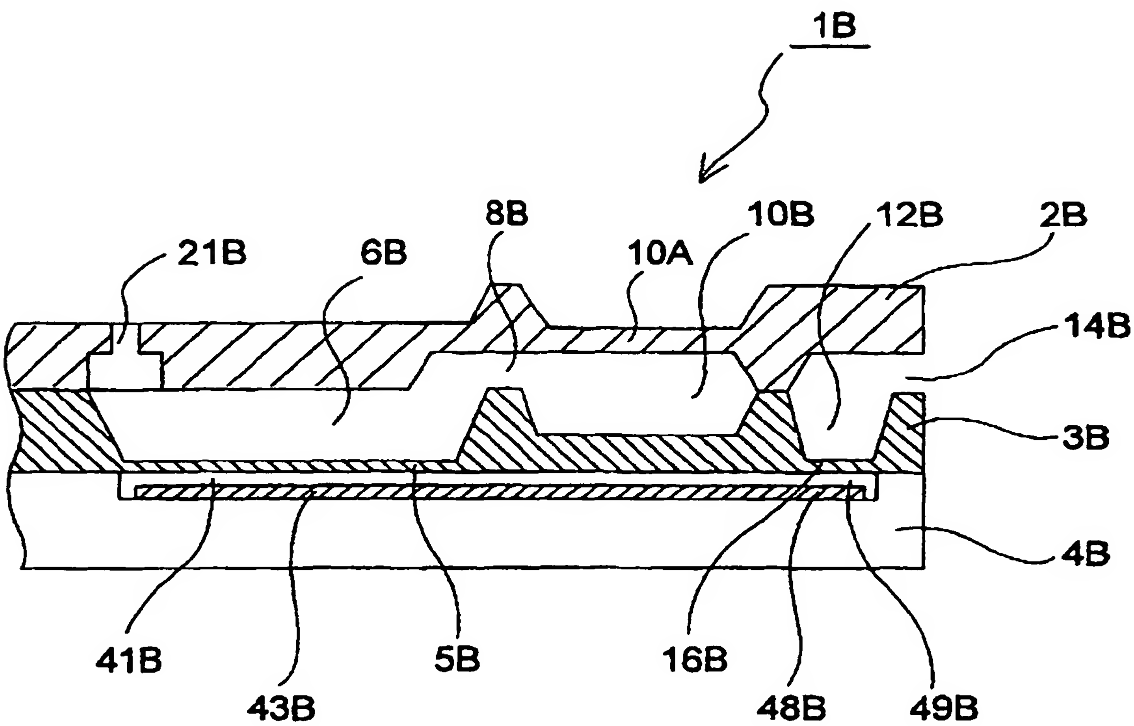


FIG.9



Third Embodiment

FIG.10

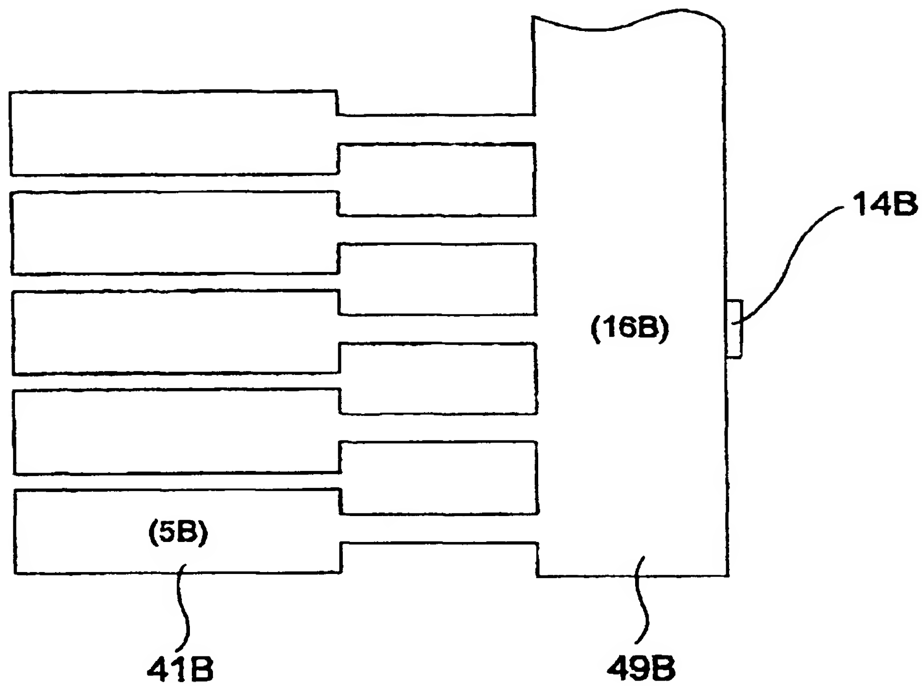


FIG.11

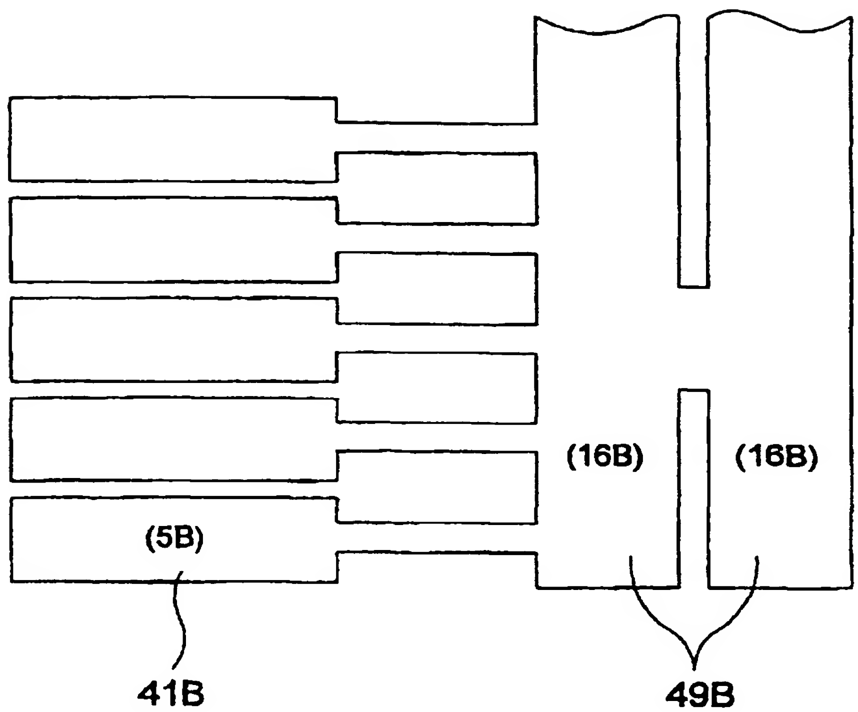


FIG.12

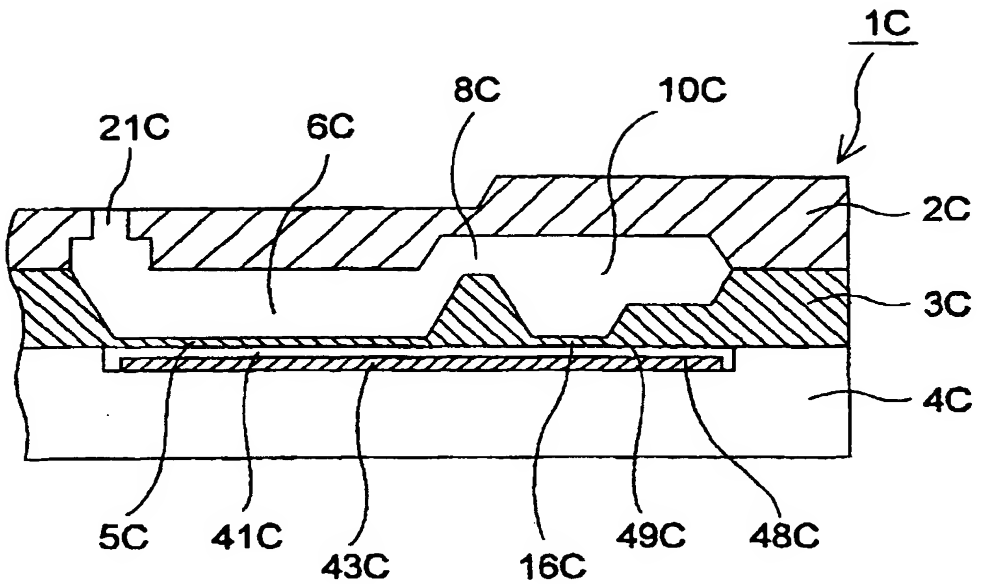
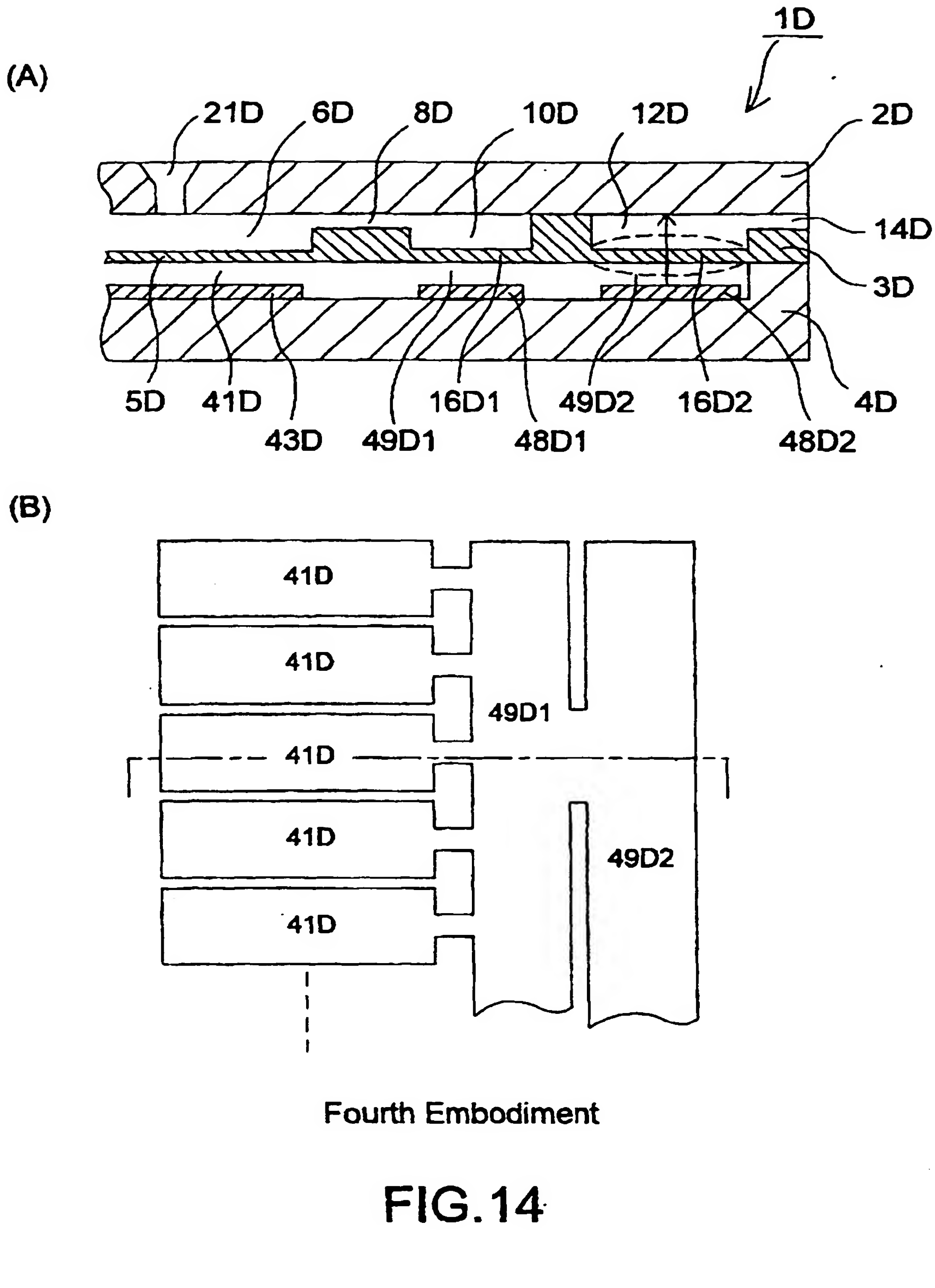


FIG.13



Fourth Embodiment

FIG.14

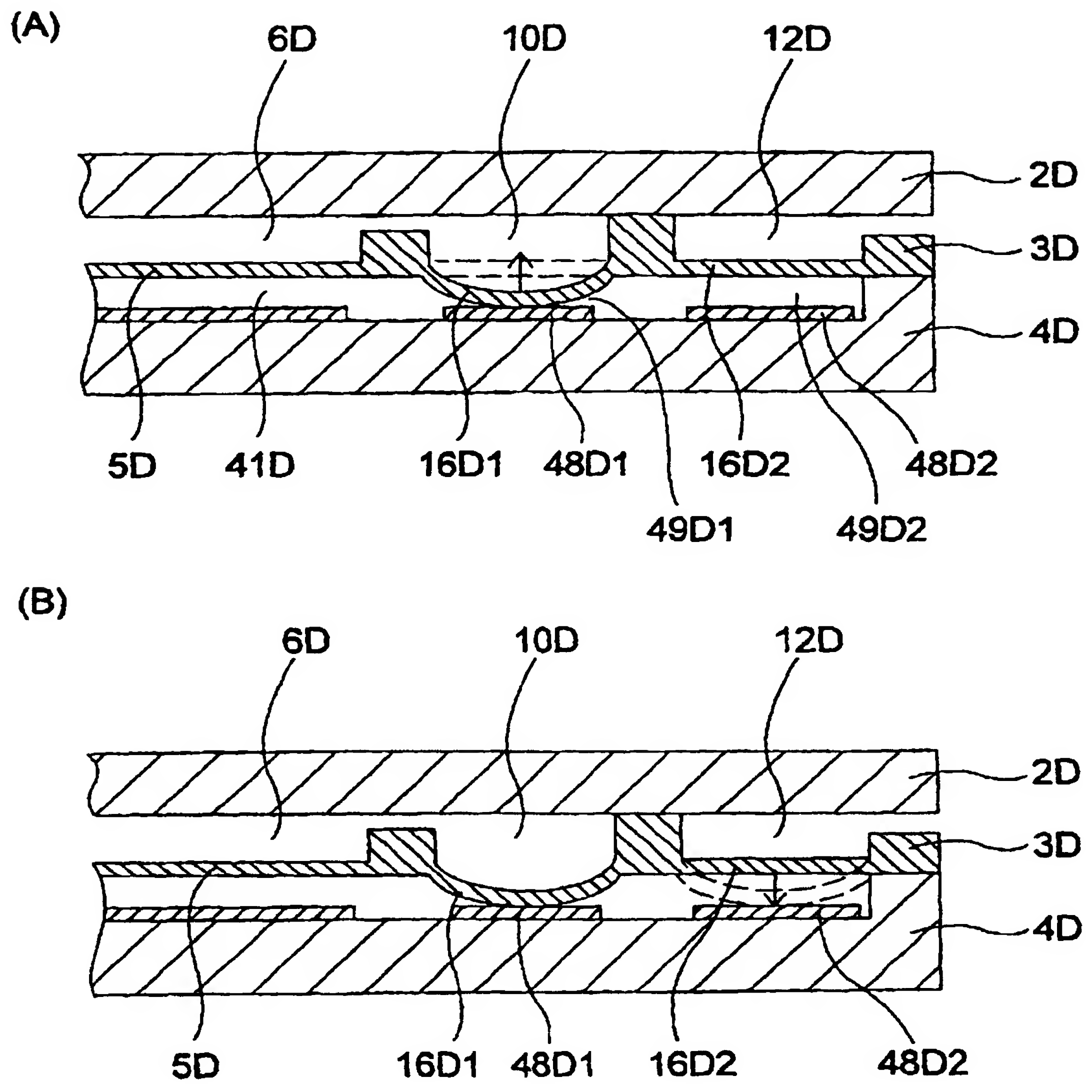

(A)
6D
10D
12D
2D
3D
4D
5D
41D
16D1
48D1
16D2
48D2
49D1
49D2
(B)
6D
10D
12D
2D
3D
4D
5D
16D1
48D1
16D2
48D2

FIG.15

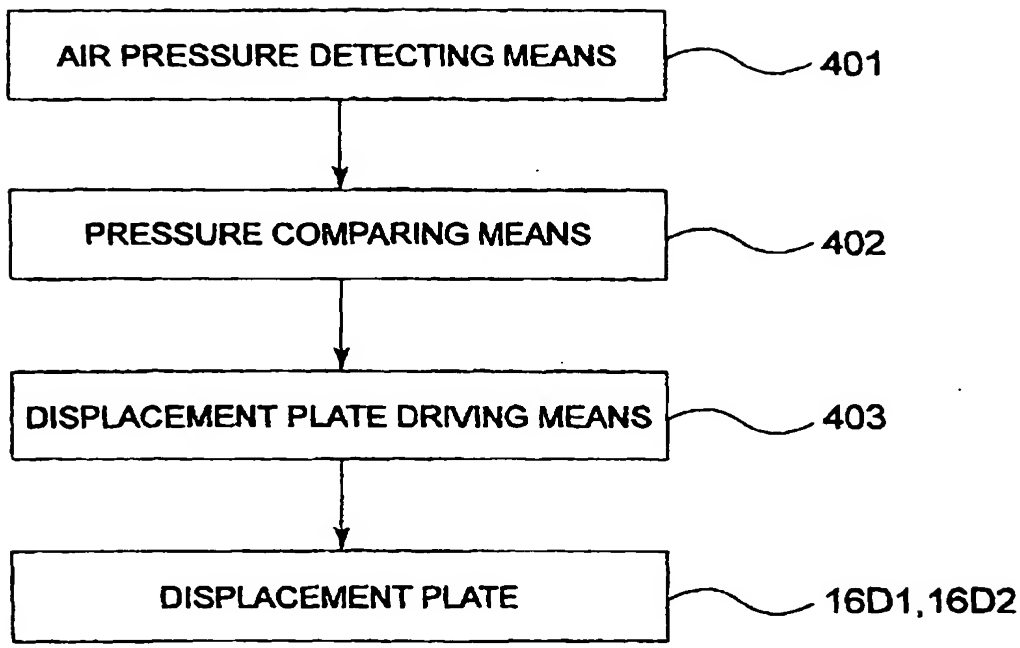
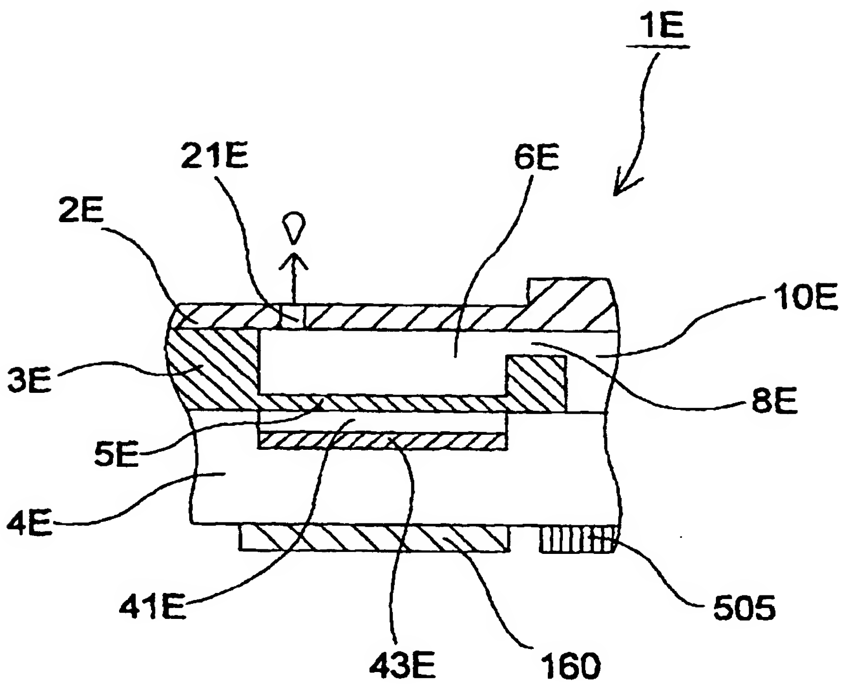

AIR PRESSURE DETECTING MEANS
401
PRESSURE COMPARING MEANS
402
DISPLACEMENT PLATE DRIVING MEANS
403
DISPLACEMENT PLATE
16D1,16D2

FIG.16



Fifth Embodiment

FIG.17

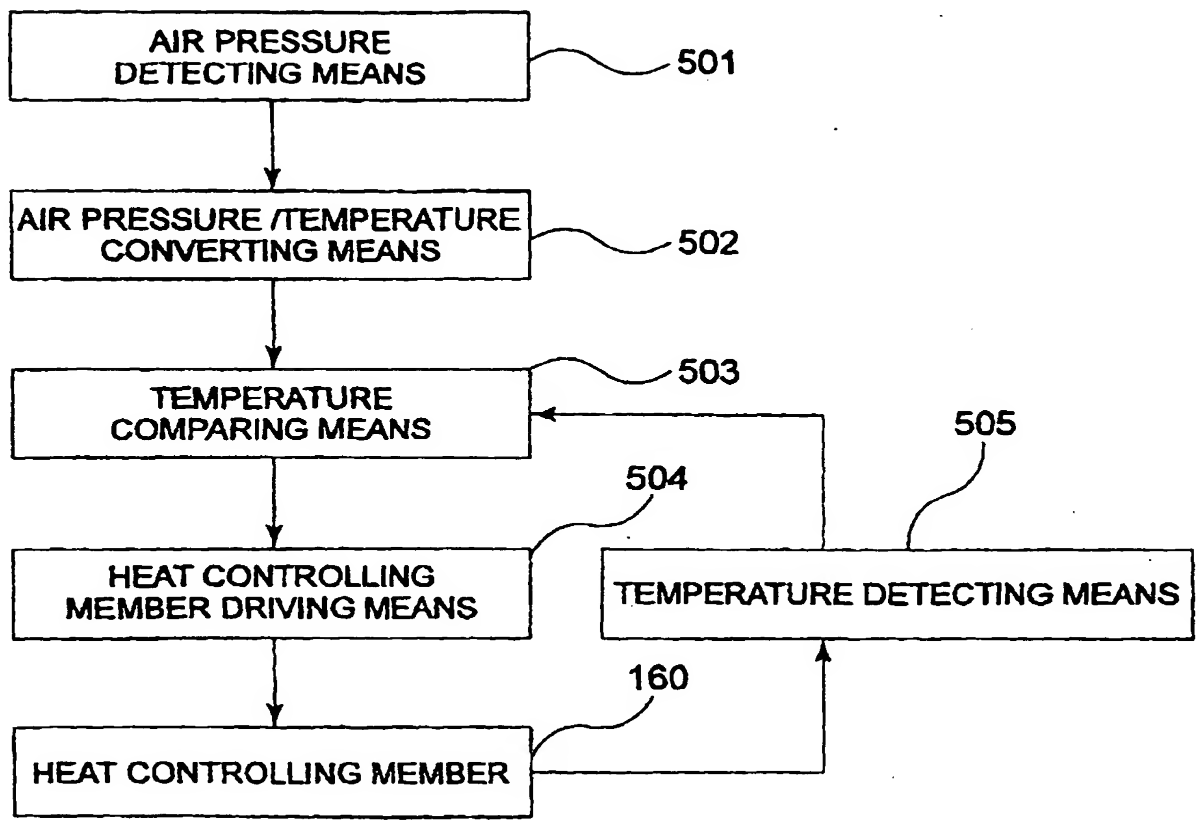

AIR PRESSURE DETECTING MEANS
501
AIR PRESSURE /TEMPERATURE CONVERTING MEANS
502
503
TEMPERATURE COMPARING MEANS
505
504
HEAT CONTROLLING MEMBER DRIVING MEANS
TEMPERATURE DETECTING MEANS
160
HEAT CONTROLLING MEMBER

FIG.18

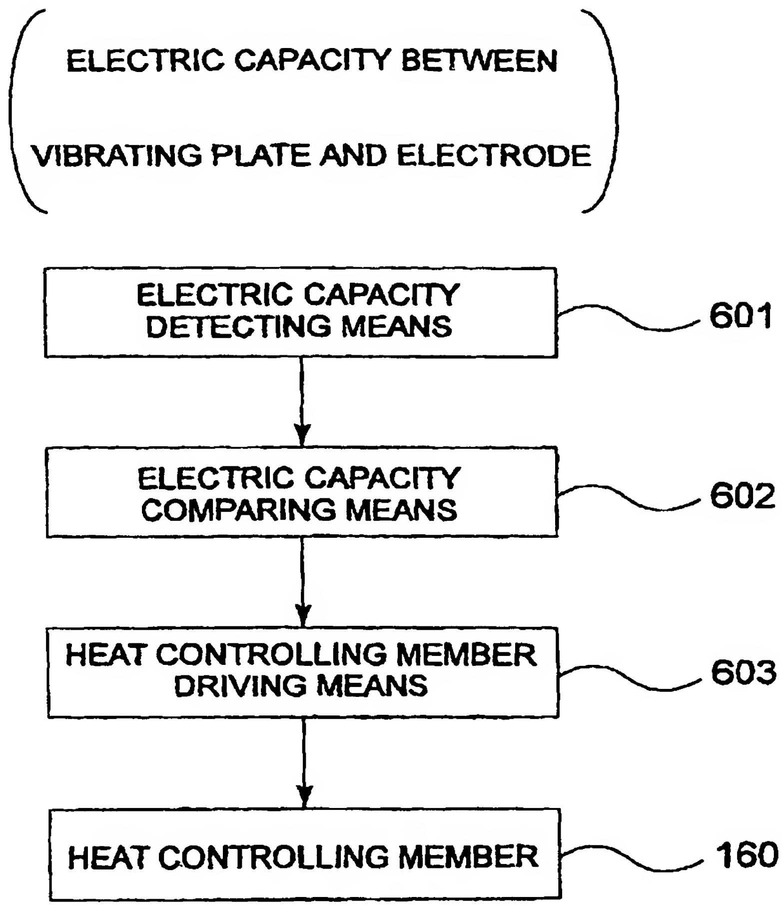

ELECTRIC CAPACITY BETWEEN
VIBRATING PLATE AND ELECTRODE
ELECTRIC CAPACITY DETECTING MEANS
601
ELECTRIC CAPACITY COMPARING MEANS
602
HEAT CONTROLLING MEMBER DRIVING MEANS
603
HEAT CONTROLLING MEMBER
160

FIG.19

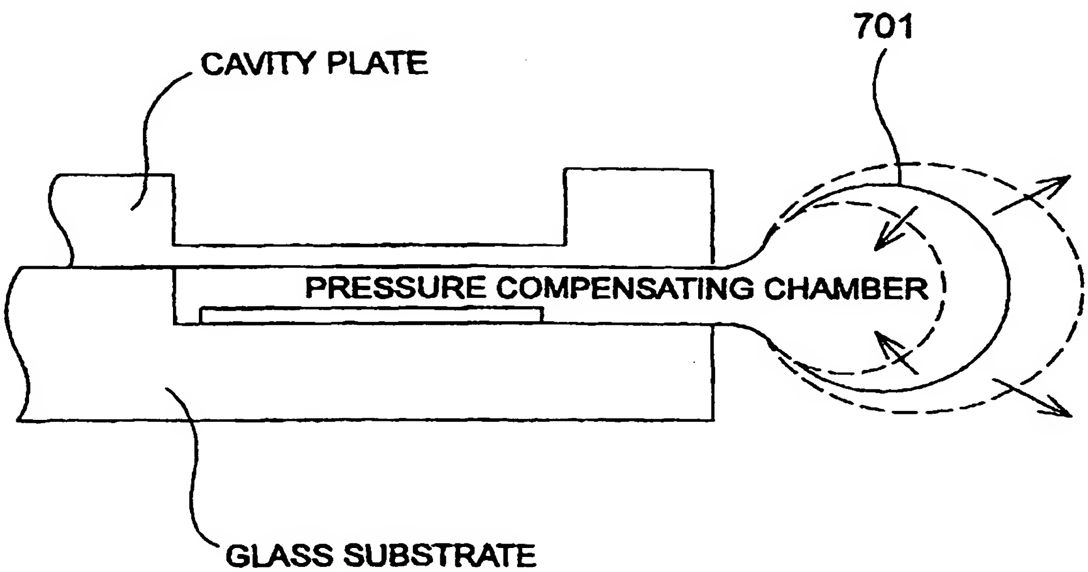

701
CAVITY PLATE
PRESSURE COMPENSATING CHAMBER
GLASS SUBSTRATE

FIG.20

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP99/01341

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl^6 B41J2/045, B41J2/055

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl^6 B41J2/045, B41J2/055

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Toroku Jitsuyo Shinan Koho 1994-1999
Kokai Jitsuyo Shinan Koho 1971-1999 Jitsuyo Shinan Toroku Koho 1996-1999

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 10-44407, A (Ricoh Co., Ltd.), 17 February, 1998 (17. 02. 98) (Family: none)	1
A	JP, 10-16210, A (Fuji Xerox Co., Ltd.), 20 January, 1998 (20. 01. 98) (Family: none)	1
A	JP, 9-314837, A (Seiko Epson Corp.), 9 December, 1997 (09. 12. 97) (Family: none)	1

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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14 June, 1999 (14. 06. 99)	22 June, 1999 (22. 06. 99)

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